Rear patterned ultrathin Si for single and tandem applications

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The main powerhouse of the photovoltaic industry nowadays is silicon. Standard Si cells are of around 150 µm thickness. They use micro-pyramids (order of 10µm) to increase the absorption for the otherwise weak absorber Si. Thinning down the silicon even more[1], <50 µm, is desirable towards increasing the efficiency of the cell[2], the number of cells obtained from each ingot, and to obtain flexible devices[3]. Furthermore, to go beyond 30% efficiency Si has to be combined with top subcells (hybrid tandems) with higher bandgap (>1.6 eV), (perovskites[4] or III-Vs[5]). However, the integration of these technologies with the standard micro-pyramids is problematic due to size (similar to the epitaxy layers) or deposition methods.

Here, we present our recent numerical results in exploring the use of a planar Silicon cell with a light-trapping scheme based on a rear- patterned structure in amorphous Silicon (a-Si), Figure 1. We explore ultrathin single-junction Si cells (10 µm and 12 µm) and its combination with a realistic tandem cell using a 1.7 eV (AlGaAs) top-cell. The light-trapping structures studied are hyperuniform/quasi-random structures.[6] These types of patterning are attainable through several self-assembly techniques (polymer-blend[6], Metal Assisted Chemical Etching (MACE)[7]), enabling a low-cost and up-scalable process. The design is focused on decoupling the nanostructured layer from the cell to minimize surface recombination generated by the addition of the nanostructure, as otherwise is expected to degrade the V_{oc} of the final device.

For the 10 µm-thick Si single-junction cell, we observe an absorption comparable to a Lambertian absorber, Fig. 1 (c). We present here simple designs inspired by symmetry considerations in the reciprocal space, with still plenty of room for optimization. With this rear-side patterning and a flat top surface, the integration of this architecture into tandem solar cells is straightforward. As an illustration, the AlGaAs(2.5 µm)/Si (12 µm) tandem cell shows an almost perfect current matching with the top cell at 18.6 mA/cm² without taking in account luminescent coupling that will increase the Si cell current. The same design could be extended to perovskite on ultrathin silicon tandem solar cells.

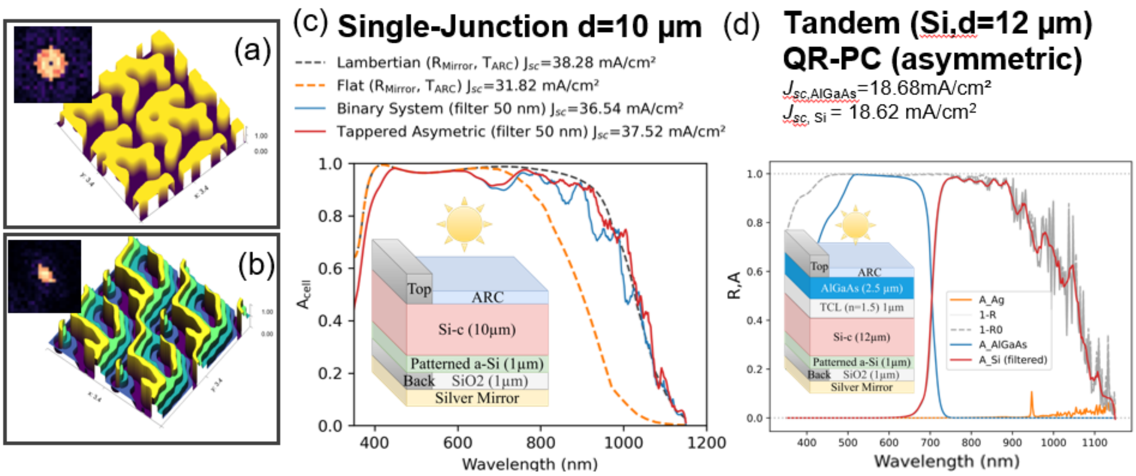

Figure 1(a)-(b) Hyperuniform, Quasi-random structures in a-Si with symmetric and asymmetric reciprocal space (inset). (c) Absorption of the single ultrathin Si cell for analytic cases, planar and Lambertian, and for the two QR structures. (d) Tandem with ultrathin Si of 12µm the structure from (b) showing current matching at 18.6 mA/cm².

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